Technology Requirements List from Breakout Session: All Requirements Have Equal and High Priority

1. Forward Solar Cell Technology Experiment
2. Electrostatic Discharge Arcing of Modern Circuit Boards, Cables, and Connectors
3. New Charge Sensing Devices and Validation
4. Deep-Dielectric and Differential Surface Charging Monitor
5. On-board Electrostatic Discharge Pulse Monitor for Integrated Circuit Testing Boxes
6. Solar Array Arc Mitigation
7. Devices to Control Surface Charging
8. Miniaturized Smart Langmuir Probe Electronics

Technology #1: Forward Solar Cell Technology Experiment

- **Background: Many recent solar array anomalies resulted in significant loss of mission capability up to and including mission failure.**
  - The SET-funded analysis project, “SAVANT Analysis of Microelectronics and Photonics Testbed Solar Array Data," showed significant uncertainty in predicting solar array performance in a proton-dominated orbit.
- **Issue: The validity of existing test protocols for advanced solar array technologies, including combined effects testing of large area coupons are questionable**
  - A flight experiment to obtain space data to validate ground test protocols for advanced solar array technologies with environment monitors is required to resolve this uncertainty.
    - **Experiment Requirements: An unobstructed view of the Sun for at least 5 to 10 minutes on a periodic basis throughout the mission.**
- **Correlative environment measurement requirements:**
  - Number of protons per cm^2 with energies down to 100 keV; temperature; solar angle of incidence
- **Environments of interest: Proton-dominated environments**

Technology #2: Electrostatic Discharge Arcing of Modern Circuit Boards, Cables, and Connectors

- **Background: FR4 circuit boards are known to spark in space with peak pulses of up to 2 amperes due to accumulation of stopped high-energy electrons.**
  - FR4 is a conductive material, so pulsing can be attenuated by covering the FR4 with 80 mils Al, and a shielding guideline exists.
- **Issue: No shielding guidelines exist for materials other than FR4.**
  - Kapton boards are 100 times less conductive than FR4 and will probably spark under typical shields.
  - Typical spacecraft materials need to be exposed to un-attenuated or lightly shielded space radiation while monitoring the pulses to collect data to validate a shielding design guideline.
  - Charge-in-the-pulse, and time of occurrence need to be monitored during the exposure.
- **Beneficiary: Use of Commercial-Off-the-Shelf technology in space**
- **Correlative environment measurement requirements:**
  - Electron and proton flux/energy spectra.
- **Environments of interest: GTO, Molniya, and GEO environments**

Technology #3: New Charge Sensing Devices and Validation

- **Background: When more than one device to measure floating potential was used on a spacecraft, the measurements did not agree with each other.**
- **Issue: Measurements of the absolute (spacecraft chassis) floating potential in space are needed to improve charging models, to monitor space weather, to evaluate charge mitigation techniques, and to improve space plasma measurements.**
  - A flight experiment should inter-compare several existing devices with each other and with new devices.
  - The flight experiment needs to go to space, because the induced space plasma environment cannot be duplicated in ground facilities.
- **Correlative environment measurement requirements:**
  - Spacecraft orbit/attitude
- **Environments of interest:**
  - Low Earth Orbit, Planetary Orbit, Solar wind environments

Technology #4: Deep-Dielectric and Differential Surface Charging Monitor

- **Background: High-energy particles, usually electrons, penetrate into insulating materials to produce threatening internal charging and electric fields.**
  - The high field strengths are responsible for generating sudden pulsed dielectric discharges to produce spacecraft anomalies and high voltage insulator breakdowns.
  - The electric fields evolve slowly according to charge deposition and conduction currents that are difficult to model.
- **Issue: Theoretical predictions of the fields after a day or more and the surface floating potential of a floating insulator surface are not validated with space data.**
  - Validations are needed to provide for pulse-free operation of the insulator materials in space.
- **Correlative environment measurement requirements:**
  - Flux/energy of electrons and protons.
- **Environments of interest: GTO, Molniya, GEO or perhaps high-inclination LEO orbits**

Technology #5: On-board Electrostatic Discharge (ESD) Pulse Monitor for Integrated Circuit Testing Boxes

- **Background: Many integrated circuits need to be tested for ionizing radiation effects in space such as single event effects, total dose, enhanced low dose radiation susceptibility, and other radiation effects.**
- **Issue: Transient ESD pulses interfere with the tests, but no device exists to monitor the pulses so that effects from radiation can be separated form effects from pulses.**
  - A transient pulse monitor (TPM) needs to be developed to measure the time of occurrence and total charge in pulses so it can be placed on integrated circuit test circuit boards.
  - The TPM should have the capability to sense the radiofrequency signal resulting from pulses anywhere in the box that is larger than the RF generated by normal box operations.
- **Correlative environment measurement requirements:**
  - None
- **Environments of interest: All environments**

Technology #6: Solar Array Arc Mitigation

- **Background: Several spacecraft have been damaged recently by spacecraft charging that is caused either by solar substorms in MEO/GEO or by high voltage arrays in LEO.**
  - The possibility of damage from charging has also necessitated the addition of a plasma contactor on the International Space Station.
  - Several new techniques for preventing or mitigating arcs on solar arrays have been tested in ground tests but have not been validated in space.
- **Issue: Flight validation of new devices is required, because a streaming plasma at the low LEO electron temperature and realistic spacecraft charging conditions cannot be achieved in ground tests.**
  - Flight validation would require that several solar array designs that are biased to about -200 volts are flown with and without arc mitigation techniques.
- **Correlative environment measurement requirements: Plasma**
- **Environments of interest: LEO or MEO environments**

Technology #7: Devices to Control Surface Charging

- **Background: Traditional spacecraft charging (caused by solar substorms) has damaged several satellites in GTO and GEO orbits.**
  - Concepts for new devices to control surface charging have been developed as a result of the failure investigations.
    - **These new devices to control charging may decrease or eliminate the need for xenon expellants and the associated complicated and massive control circuitry.**
- **Issue: Flight validations of the new concepts are required before they are used in spacecraft.**
  - Validation in space is needed, because the potential barriers and the low neutral plasma density of GEO/MEO cannot be duplicated in the lab.
  - Power sources that produce 100 V or more are required to complete the validation.
- **Correlative environment measurement requirements: Plasma**
- **Environments of interest: MEO/GEO environments**

Technology #8: Miniaturized Smart Langmuir Probe Electronics

- **Background: Langmuir probes are the standard space plasma environmental monitors, returning both the plasma density and temperature -- quantities essential to spacecraft charging.**
- **Issue: Past Langmuir probe electronics were bulky, heavy, and required significant power and data interfaces.**
  - Miniaturized Langmuir probe electronics that return just the data of interest, i.e., density and temperature, (and therefore require minimal interfaces) could be flown routinely on spacecraft, providing valuable information about spacecraft charging conditions.
  - Flight validation is necessary before spacecraft would routinely use the miniature probes.
  - Space flight is required, because a streaming plasma at the low LEO electron temperature cannot be achieved in ground tests.
- **Correlative environment measurement requirements: Plasma**
- **Environments of interest: LEO environments**